

Feasibility Study of Far-Field Methods for Calibrating Ground Station Delays

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The first phase of a study to survey various methods of directly implementing a far-field means of calibrating ranging systems is described. Consideration is given to means of determining test range distances independent of microwave techniques.

I. Introduction

This is the first phase of a study to survey various methods of directly implementing a far-field means of calibrating ranging systems. For 13-cm wavelength, the far field begins at a distance of 65 km for a 64-m-diameter antenna. Because this distance is sufficiently large to preclude the normal collimation tower approach, various free-moving platforms were surveyed to determine their suitability to this task.

An important associated problem, that of determining the absolute range to an accuracy <0.5 m over the range test distances, was addressed. It appears that it would be desirable to determine the transponder range by means independent of microwave techniques. A laser system has been suggested, since the wavelength employed is sufficiently different from the microwave to be affected differently by the transmission media.

II. Balloons

The Weather Bureau routinely probes the atmosphere with Rawinsonde balloon systems. These balloons are small (~ 2 m

diameter), and the instrument package is very light (~ 2 kg). An altitude of about 30 km is achieved during flight.

A balloon large enough to carry a transponder package, which can weigh as much as 20 kg with power supply, would be much larger (~ 5 m diameter) than those utilized for Rawinsondes. The larger the balloon, the more difficult it is to launch, especially under windy conditions, and this considerably complicates the logistics and procedures.

Balloons, by their very nature, can trace rather capricious paths due to winds of varying speed and direction at different altitudes. These motions could make accurate tracking of the transponder package difficult, particularly for a laser ranging system.

Not negligible is the potential loss risk of an expensive transponder package.

III. Aircraft

A high-performance aircraft can be used as a transponder platform. Perhaps the outstanding advantage of the aircraft is the positive control of the transponder at all times, both in its location and operation. The aircraft can be flown on a prescribed flight path and the actual range to the aircraft determined by a laser ranger. A malfunctioning transponder can be brought back for repair. The possibility of losing the transponder package is essentially nil.

The main disadvantage of an aircraft platform is the altitude achievable by aircraft. Excluding special high-performance military aircraft, usable altitudes are limited to about 13.5 km. This altitude translates into an elevation angle of about 12 deg at a slant range of 65 km. Because of the greater far-field distance, aircraft are not usable for X-band. Achievable elevation angles (~ 3 deg) are below limits.

IV. Satellites

A geostationary satellite would make a good transponder platform. Such a platform is easily in the far field of a 64-m-diameter antenna at any foreseeable frequency. Other advantages are the availability of the transponder at any time and good elevation angles. Elevation angles up to about 50 deg are possible, depending on the location of the receiving station and the satellite.

Placing a transponder on the moon is a special case. The geometry is somewhat more complex and is time-dependent. Operation of this transponder will require use of a ranging system similar to that used in the Lunar Laser Ranging Experiment. Accuracies in the region of 40 cm have been achieved at lunar distances.

Cost is an important factor in the utilization of satellites for a transponder platform. Space-qualified components are enormously expensive, in addition to the launching costs. The Space Shuttle may offer a considerable reduction in launch costs.

V. Independent Ranging Systems

The use of a ranging system not employing microwaves appears attractive. The outstanding candidate is the laser ranging system. A system developed for the LAGEOS Program is capable of determining distances to about 200 km with an accuracy of a few centimeters. Such systems are very expensive and complex. They must have an autotracking capability for use with rapidly moving targets such as balloons, aircraft, and nonsynchronous satellites including lunar packages.

A nontracking laser system, the Geodimeter, can determine distances up to 50 km with an accuracy better than 10 cm.

Exotic high-performance pulse radars were not considered for independent ranging systems. Though techniques are available to resolve return echoes to an accuracy of about 30 cm, transmission media effects may preclude the use of pulse radars for the range problem because of frequency commonality.

VI. Summary

Several methods of far-field ranging calibration have been surveyed. All of these approaches have been direct; the placement of the transponder is in the far-field region. All of the transponder platforms are free-moving, requiring a means of accurately determining the range to an accuracy of <0.5 m.

The leading approach at this time seems to be the aircraft but would be usable only at S-band. Satellites, whether geosynchronous or lunar-based, seem to be prohibitively expensive.

Future directions of this study should be towards refining some of the cost performance numbers and investigating alternative approaches such as near-field methods.